Forest cutting and regeneration methodology on Changbai Mountain

DAI Li-min [1], SHAO Guo-fan[1], CHEN Gao[1], LIU Xin-shuang[2], GUAN Zhi-peng[3], LI Yang[4]
[1]*Institute of Applied Ecology, Chinese Academy of Sciences, Shenyang, 110016, P. R. China*
[2]*Shenyang Agriculture University, Shenyang 110161, P. R. China*
[3]*Fenghuang Mountain Landscape Management Bureau, Chaoyang, 122000, P. R. China*
[4]*National Nature Reserve of Changbai Mt., Antu 133613, Jilin Province, P. R. China*

Abstract: This paper discussed the characteristics of degenerated forest ecosystems in Changbai Mountain area, which include over-harvest natural forest, typical secondary forest, derived forest, and artificial forest. Forest cutting and regeneration methods that were historically used in the region were summarized. They include diameter-class selective cutting, clearcutting, upbringing selective cutting, and selective cutting. We proposed cutting methods for the broad-leaved Korean pine mixed forest, spruce-fir forest, and larch forest. The measures for restoring the original mixed forest ecosystems were recommended.
Keywords: Degraded ecosystems, Regeneration, Selective cutting, Clearcutting
CLC number: S782.1 **Document code:** A **Article ID:** 1007-662X(2003)01-0056-05

Introduction

Changbai Mountain lies in the southeast of Jilin Province and was used to be covered with contiguous natural forests. Changbai Mountain area belongs to temperate monsoon climate zone, characterized with abundant precipitation, warm and rainy summers, and chilly and dry winters. The soil type is brown forest dark soil with thick soil layer and heavy humus. These climate and soil conditions facilitate the distributions and growth of some coniferous and broad-leaved tree species. The native forest vegetation is broad-leaved Korean pine mixed forest, which is composed of conifers such as *Pinus koraiensis,* and broad-leaved trees such as *Tilia amurensis, Betula costata, Fraxinus mandshurica, Juglans mandshurica, Acer spp. etc.*. Changbai Mountain is in the central distribution area of the broad-leaved Korean pine mixed forest in Northeast China.

Forests on Changbai Mountain not only have rich species that are found in the temperate zone as they are composed of many natural forest stands. The area is one of most important timber production bases in China and also provides a significant amount of wood and non-wood products. Forests on Changbai Mountain area protect eco-environments for many areas of northeast China and play important roles in the region and the entire nation's economic development (The Editorial Committee of Chinese Forests 1997). As far as the whole east portion of northeast mountainous region is concerned, in the last one hundred years, the forests suffered from extensive damages by human. The area and stocking of the original forests declined sharply, and the eco-environments deteriorated due to human disturbance. Extensive forest cutting lasted 40-50 years. As a result, the broad-leaved Korean pine mixed forest that was used to be abundant now exists only in a few natural reserves and some remote mountainous regions, where the broad-leaved Korean pine mixed forest, spruce-fir forest, and larch forest account for about 80% resources. The volume of Korean pine, larch, and spruce-fir trees accounts for only 6.5% of the total timber stock volume in the over mature mixed forests within Yanbian State-Owned Forest Management Bureau enterprises. How to management the remaining forests and regenerate the harvested forests in the region are critically important in terms of enhancing ecological functions and social benefit of the forest ecosystems. The restoration of the forest resources will help improve the living environment of people in the region, and can directly affect socio-economic sustainable development of forested area in northeast China (Huang 1992; Xu 1997; Xu 1985).

Characteristics of the degenerated ecosystems

In the 20th century, naturally regenerated broad-leaved Korean pine mixed forest suffered from extensive human disturbances. The forest ecosystems in Changbai Mountain area now have different degrees of degeneration and characteristics due to different durations, intensities, frequencies and types of the disturbances. In whole distribution region of broad-leaved Korean pine mixed forest, the differences between the original natural forest and the regenerated secondary forests vary in dominant tree species, degeneration degrees, and natural restoration processes and period (Liaoning Provincial Society of Forestry, 1982).

Foundation item: Supported by "100-people" project from CAS; NKBRSF (Grant No. G19990433407); NKTRDP (2001BA510B07 & 2002BA516A20); IAE (KZCX2-406 & SCXZD0101), the National Natural Science Foundation of China (NSFC30170744).
Biography: DAI Li-min (1960-), Male, PhD, Professor in Institute of Applied Ecology, Chinese Academy of Sciences, Shenyang 110016, P. R. China E-mail: lindai@sina.com
Received date: 2002-02-08
Responsible editor: Chai Ruihai

Over-harvest natural forest

Some of the mixed forest was damaged by removing valuable trees during 1930s-1940s. The remained forest stands have both some original tree species and some secondary species, but lack Korean pine and some good-quality broad-leaved trees. Such a forest is called over-harvest natural forest. The canopy cover is 0.3-0.6 and there are a large number of snags and logs in the stands. The structure and productivity are normally lower than the original and secondary forests. It has obvious regeneration and succession stories where valuable original tree species are found. If low-intensity selective cutting is used, stand stock can be restored in 20 years, but the restoration of density need longer time. The restoration of this type of degraded forest can be promoted by intensive tending (Editorial Committee of Chinese Forests 1997).

In Yanbian Korean Autonomous Region, there are 370 000 hm^2 and 54 630 000 m^3 of over-harvest forest, accounting for 49.9% of total forest area and 17.1% total forest stock, respectively. The over-harvest forest is distributed on north-, northwest- and northeast-facing slopes or some ridges in the middle elevations (500-1000 m).

Typical secondary forest

There are 14 660 000 hm^2 of secondary forests in northeast China. There are a total of 1 740000 hm^2 of natural forest in low elevation area (250-500 m) in Yanbian Korean Autonomous Region, which can be divided into steep slope Curculio forest, sloping field Basswood black-birch Curculio forest, moderate slope Poplar/*Betula platyphylla* forest, slope maple elm with some tree forest, slope walnut forest, low-wet land *Fraxinus mandshurica*/white-birch forest, stream low land Walnut /*Fraxinus mandshurica* forest, and low-wet land white-birch forest etc.. The natural forest accounts for 61.9% of total forest area and its growing stock is 158 880 000 m^3, accounting for 49.9% of the total forest stock. Even the Changbai Mountain Forest Natural Reserve has 7 550 hm^2 of typical secondary forest, because of the fire and cutting, and 11 368 hm^2 wind fallen area. The secondary forests become the dominant forest type in eastern mountain area of northeast China.

Derived forest

The derived forest is the resurgent secondary community resulting from the secondary succession of secondary bare land that is formed after the degraded original community is cut with small area, reclamation or burning in wildwood region. The dominant tree species are normally shade intolerant and fast-growing. The forest stands are characterized with single canopy layer and even-age structure. Because of its small size in area and surrounded by original communities, the stand can resume in one generation and become the natural stand in the next generation. These derived forests have the characteristics of secondary forest if cutting area is large enough.

Artificial forest

The artificial forests are commonly planted because of their fast growing, high productivity, short cultivation cycle and easy management. Planting forests may not only increase timber production but also help environmental protection. At present, man-made vegetation (including forest and grassland) has been commonly used for the restoration of regional ecosystems and biodiversity.

In summary, there are some original ecosystems well protected like broad-leaved Korean pine mixed forest, and various degraded ecosystem in Changbai Mountain area. Further more, Changbai Pine Forest *Pinus densiflora var. sylvestriformis* (Taken.) Q. L. Wang, and Changbai Larch Forest (*Larix olgensis*), some swamps and meadows, that make up of the abundance ecosystem types on Changbai Mountain (Xu 1991).

History of forest cutting methods

Forests on Changbai Mountain were not cut until a century ago. Before 1949, the forests were cut in a way that only big and valuable trees were removed from the forests. After the establishment of the People's Republic of China, planned cutting has been carried out in Changbai Mountain area. Several forest cutting methods were used. They include large-area clearcutting, small-area clearcutting, and selective cutting. In 1956, forestry department formulated some forest regulations successively, such as "Regulations of Main Cutting of State Owned Forests" (1956, 1960), "Forest Cutting and Renewal Regulations" (1973), and "Forest Cutting and Regeneration Management" (1987). These laws and regulations determined the way the forests were cut and regenerated in China. Diameter-class selective cutting, clearcutting, upbringing selective cutting, and selective cutting have been adopted successively in Changbai Mountain area (Zhao 1990).

Diameter-class selective cutting

The diameter-class selective cutting was applied in many places of Changbai Mountain area in 1952. The post cut area was naturally regenerated. This cutting method had some advantages over the 'select the best' cutting methods used before 1949. This new method regulated cutting intensity and promoted cutting diameter-class of every tree species, and at the same time, required that not only cut the purpose trees, but also remove the over-mature trees, disease and unhealthy trees, and dead trees. This method also opened up space for young trees that had potential to growth. After 1954, the diameter-class selective cutting has been stopped because this method could not meet the need of high timber production. As a result, cutting intensity increased. The big opens of forest canopies restricted the growth of seedlings and saplings that had been regenerated before forest cutting. Light-like shrubs became dominant on forest floors.

Clearcutting

Since 1956, timber demand in China continued to increase. Some cutting methods, such as narrow-strip clearcutting, same-strip or different-strip spaced clearcutting and sequence clearcutting, have been used in Changbai Mountain area. These forest cutting methods overestimated the power of human and overlooked the natural or artificial regeneration of forests, making large areas of original forest to be secondary forests, shrubs, wild lands, or man-made larch forests. The regeneration environment and various biological resources of forest ecosystems were damaged to a great degree. Serious ecological consequences took place in Changbai Mountain area.

Upbringing selective cutting

Based on experiments, the upbringing and cutting both caught attention to Wuminhe Forest Bureau in Xiaoxinan Ling area, Upbringing selective cutting was brought forward. Under the regulation of upbringing selective cutting, the cutting intensity should not exceed 60% of the total stand stocking before cutting, and canopy density after cutting should be kept over 0.4, and at least 300 trees with DBH greater than 8 cm of haleness objective tree species per ha should be remained. The density of the saplings of major tree species should be over 3000/hm^2 in cut-over areas.

This cutting method was firstly pushed in Spruce-Fir Forests in Changbai Mountain area in 1964, and was later expanded to some mixed forests and well naturally regenerated stands with a large number of small diameter-class trees. The principles of upbringing cutting was summarized for easy field applications: cut bad and keep good (cutting ill and rotten, bend, and damaged trees), cut old and keep strong (cutting the overlord trees in the canopy story to liberate pressed trees), cut coarseness and keep excellent (cutting secondary tree species and keeping conifer and valuable broad-leaved tree species), cut close and keep sparse (keep uniformity after cutting) and over 0.4 canopy. The growth of reserved trees could be promoted by some measures, such as the width of collection timber road is less than 7m, and cutting intensity is less than 50%, and 0.5 canopies and over 350 reserved trees per hectare.

Mature overstory trees periodically were selectively cut and understory young trees were hold owing to upbringing selective cutting. Therefore, forests could continuously provide timber and various biology resources and keep eco-environment stable. This cutting method relaxed the resource crisis of some forest bureaus in a certain extent and could help sustainable manage the original forest.

Cutting and regeneration methods

Principles of determining a cutting method

Whether the regeneration of forest was a concern or not in forest cutting reflects the scientific attitude on the use of forests. Forest regeneration is the key of forest management, and its' success depends on forest cutting methods. In other words, a cutting method becomes the magnitude means of successful regeneration. In the past, forests were excavated mistakenly driven by the only need for timber production. For the most of time, forest cutting exceeded forest growing. Sometimes, forest regeneration and silviculture were not actually taken account. These manners of forestry development had brought infinite calamity to many countries over the world. Resources crisis, ecological crisis and economic crisis that restrict the socioeconomic development in northeast China are the examples of the consequences. Before 1980s, clearcutting was not a major cutting method in Changbai Mountain area (Table 1). But the proportion of clearcutting increased to 39.3% in the period of 1986-1990. Since 1996, clearcutting was almost eliminated in Changbai Mountain area (Du Wenyan, personal communication).

Table 1. A summary of forest cutting in the Baihe Forest Bureau from 1972 to 1990

Year	Summation	Selective cutting		Clearcutting		Data source
		Area (hm^2)	Every year (%)	Area (hm^2)	Every year (%)	
1972 - 1981	11 973	9 460	79	2 513	21	Ref. 1
1986 - 1990	23 129	14 054	61	9 075	39	Ref. 3

Artificial regeneration was adopted in the cutover land of clearcutting, and often failed because of delayed regeneration efforts. Even if the regeneration was succeeded, the mono-cultural conifer pure stand like Korean pine or Larch forest would produce a series of ecological problems in the subsequent development because of the singleness of tree species and simple structure.

By comparing the natural forest with the artificial forest, it was proved that the former is in evidence superior to the latter in the ecological functions (Zhang *et al.* 1999). Therefore, the determination of a cutting method in Changbai Mountain area should first favor the success of natural regeneration, and also guarantee:

1) Maintaining the health and stability of forest ecosystems; sustainably obtaining the good-quality woods, and bringing the environment maintenance into play well;

2) Accelerating the rapid restoration of native ecosystems from forests that were seriously disturbed;

3) Protecting the entire landscapes;

4) Assuring economic benefit to local people.

Cutting methods of broad-leaved Korean pine mixed forest

There have been serious debates on the cutting and regeneration of broad-leaved Korean pine mixed forest since the early stage of forest utilization in northeast China.

The focus of the debates was to use selective cutting or clearcutting. Many scholars had proved not only in theory but also in practice that selective cutting was fit for the mixed forest (Chen 1993; Luo 1997; Shao *et al.* 1995, 2000; Wang 1981; Zhang 1999; Kimmins 1996). In summary, it is anticipated that selective cutting

1) helps maintain the multistory and uneven-aged structure of the mixed forest, and therefore, protects ecological conditions of forested landscapes;
2) promotes the growth of small and mid-size trees, and therefore keeps the highest forest productivity and shorten forest cultivation cycles. Debris from cutting left on forest floors provide extra nutrients to soil;
3) prevents the fragmentation of forests, and therefore, keeps the integrity of entire forested landscapes. The multiple services of forests are assured;
4) protects the original biodiversity and structure of forest ecosystems and stabilizes forest development;
5) facilitates natural regeneration and reduces the cost of silviculture;
6) maintains ecological environment and balance, and therefore, provides the right space for all biological beings within a forest, and creates a good base for non-wood productions.

Whether the selective cutting can reach the anticipative effects depends largely on the scientific understanding and the use of selective cutting theories. The key of technique is to determine the right cutting intensity, cutting cycle, and cutting target. Based on past studies, small and lower than 30% of cutting intensity is suitable (Jilin Provincial Society of Forestry 1983; Zhang 1999), the reserved stand stock after selective cutting should be over 100 m^3/hm^2, and logging cycle should be within 15 years.

The restoration speed of forest after selective cutting is closely related to tree species and size. A good selective cutting method considers both the uses of old mature trees and growth of young trees. Cutting operations are based on the diameter-class and the quality of a stand. Dead and injured trees, as well as trees without good stem or canopy forms do not have growth potential and may restrict the growth of young trees. They are also the cutting targets even they fail to meet the cutting criteria. In contrast, even though some trees can meet the cutting criteria, but they have good forms, they may be reserved for one cutting cycle as seeding sources. Particularly, valuable and rare broad-leaved large-size trees should be reserved

Studies show that the foliage of broad-leaved trees can add the fertility of soil and avoid podzolization. Sparse canopies are good for the germination of Korean pine seeds and growth of Korean pine seedlings. If Korean pine can regenerate, the restoration of the original forest will be come practically more possible. The stand and fallen trees are the habitats and food sources of some biological consumers and decomposers. Therefore, some living broad-leaved trees, dead trees, single old woods, and coarse debris should be properly hold to assure the inhabit environment of mature forests.

Seedlings, saplings, and young trees reserved can be protected from injures if the effective direction control of tree falling is laid out in advance before cutting operation and logging. At the same time, Korean pine, *Abies holophylla* and some valuable broad-leaved tree seedlings would be planted in areas where natural regeneration is not sufficient.

Cutting methods of Spruce-Fir Forest

There is normally sufficient natural regeneration in the Spruce-Fir forest. Selective cutting should keep cutting intensity below 40% and use the natural regeneration. Table 2 shows the suitable diameter-class of cutting and reserved woods. Upbringing selective cutting should be used along the banks of rivers, near railroads and highways, on mountain ridges, and in some rocky and barren areas. A selective cutting cycle of 10 years or shorter is suitable in these areas.

Cutting methods of larch forest

Lower than 30% of cutting intensity is appropriate for larch forests in Changbai Mountain area where natural regeneration is sufficient and clearcutting can cause water table in to increase. A small quantity of 100 m narrow-strip clearcutting or 3-5 hm^2 clearcutting can be adopted in areas where natural regeneration is not sufficient; the reserved belt should be cut when forest plantations in clearcutting belt have closed canopies. In fertile sites, clearcutting can be used to prepare sites for developing fast-growth and high-productivity forest plantations.

Restoration of degenerated forest ecosystems

Degraded forest ecosystems are secondary forests formed through over-harvesting or natural disturbance of the original mixed forests, which are composed of Korean pine and associated broad-leaved tree species, such as basswood, ash, birch, curculio, elm, walnut, aspen, and maple. In degenerated forests, there are no Korean pines, spruce or fir trees in overstory, most timber trees have no little economic value, and understory regeneration is composed of mainly broad-leaved trees. In summary, degenerated forests have a common characteristic that tree species constitution and structure of Korean pine broad-leaved mixed forest are preserved except for lacking the indicator species - Korean pine. Therefore, for the over-harvested forests and secondary broad-leaved or aspen-birch forests, it is relatively easier to convert them into broad-leaved Korean pine mixed forests than to rebuild the mixed on cut-over land or burned areas. There are different measures for the restorations of different secondary forests:

Secondary broad-leaved forest with many seedlings

Those forest stands have hundreds young Korean pine and spurs-fir trees per ha. Thinning closed canopy stories is the most effective way to promote the growth of the young trees. In both Xiaoxing'an Mountain and Changbai Mountain areas, there are a large number of Korean pine and

spurs-fir young trees with 2-3 m in height in aspen-birch or curculio forests. This type of secondary forest should carry thought tending to promote the development of young trees. At the same time, middle- and small-size trees can be partially harvested. But the tending intensity should be small to avoid the photo-oxidation damage of Korean pine seedlings.

Secondary broad-leaved forest lacking seedlings

In those forests, spot thinning, gap thinning, porch thinning, and strip thinning can be adopted to introduce into Korean pine and spurs-fir trees, and plant some rare broad-leaved trees, such as basswood and ash. The goal is to increase the number of seedlings to hundreds or thousands per hectare. Relevant studies have been done in Liaoning, Jinlin and Heilongjiang Provinces. The effects of thinning on the growth of young trees were different among the young trees planted depending on thinning intensities and tree locations.

Tending of young plantation is the key of the success of afforestation. According to the rules of plantation, timely tending should be developed and belt or strip thinning should be applied in the secondary forests.

As for tree density of afforestation, it is important to assure the natural regeneration of purpose tree species. Generally, there should be 1 000 needle trees over one-meter in height per hectare after afforestation.

Planting the needle and preserving broad-leaved trees is an effective strategy to develop the broad-leaved Korean pine mixed forest. It is not recommended to plant single species larch plantation. Instead, planting Korean pine larch broad-leaved mixed forest is preferred. Thus, the broad-leaved Korean pine mixed forest can be renewed in the cutover area after the removal of larch trees. Korean pine has potential to grow to large-size trees and can continue to grow for hundreds of years. Of course, fir forest or Korean pine fir mixed forest is not a bad choice.

Conclusions and recommendations

In Changbai Mountain area, both the quantity and quality of original forests declined because of their long-term and high-intensity cutting and utilization, contributing to serious environmental problems. The comprehensive views of the forest utilization history in Changbai Mountain area revealed that forest cutting methods have been changing over time. The change itself was to the indication of efforts for finding best or optimal cutting method suitable for each forest type. However, useful lessons have been learned the hard way. There are no good or bad cutting methods per se. Forest cutting methods are recommended as long as they are suitable for forest conditions and the goal of forest management. To fully exert the power of nature is the premise, and human's activities can be helpful to make forest development most suitable for the nature. Such rules are the scientific basis for utilizing forests.

The national policy now limits forest cutting and promotes forest protection. This is an initial step toward regional forest sustainable management. If forests are cut, selective cutting is recommended because it makes fully use of the power of the forest' natural renovation, and at the same time, ensures forest stability and rapid resume. However, the misuse of the cutting intensity, cutting rotation and cutting target can also lead to forest ecosystem damage. If clearcutting is used to develop fast-growing and high-productivity plantations, it should be used in small and isolated areas. In general, a single cutting area cannot exceed 5 hm^2. Intensive silviculture and management practice are required within several years after planting seedlings. This is the key to develop high quality forest plantations in the regions.

References

Chen Dake *et al.* 1993. Forest management [M]. Harbin: Northeast Forestry University Press.

Editorial Committee of Chinese Forests. 1997. Chinese Forest [M]. Beijing: Chinese Forestry Publishing House

Huang Xiyin. 1992. Baihe Bureau Annals (1986-1990) [M]. Chifeng: Neimenggu Technology Press, p105.

Jilin Provincial Society of Forestry. 1983. The cutting and regeneration review report of Baihe Bureau in Changbai Mount forest area [R].

Kimmins, H.W., (Zhu Chunquan *et al.* Translation). 1996. Balanceable principle—issue between forestry and environment [M]. Chinese Environment Science Publishing house.

Liaoning Provincial Society of Forestry, Jilin Provincial Society of Forestry, Heilongjiang Provincial Society of Forestry. 1982. Forestry in northeast China [M]. Beijing: Chinese Forestry Publishing House, pp363-372.

Luo Juchun *et al.* 1997. The Effect of disturbance on natural Korean Pine forest foliage diversity. For Sci.33 (6): 498-503.

Shao guofan *et al.* 1995. Forest Dynamic Simulate—Concurrent Discussion on Korean Pine Optimize Management. Chinese Forestry Publishing House.

Shao guofan *et al.* 2000. Salvation broadleaved Korean pine forest: The last hope [C]. In: Zhang PeiChang (Ed). Expert Discussion on Natural Forest protection Project. Beijing: Chinese Forestry Publishing House, pp333-341.

Wang Zhan *et al.* 1981. Study on the law of stand growth in broad-leaved Korean pine forest after selective cutting [C]. In: Forest Ecosystem Research (2). Beijing: Chinese Forestry Publishing House, pp1-22.

Xu Deying, Guo Quanshui and Yanhong *et al.*1997. Study on the Influence on Chinese forest type of the climate change [M]. Beijing: Chinese Technology Publishing House, p129.

Xu Huacheng. 1991. Comparing evaluation between artificial forest and natural forest [J]. Journal of World Forestry Research, **4**(3): 50-56.

Xu Zhenbang.1985. Study on Chinese temperate zone broadleaved/Korean pine forest increasing site productivity in reason management [C]. In: Forest Ecosystem Research (5). Beijing: Chinese Forestry Publishing House, pp 57-63.

Zhang Peichang, Zhou Xiaofeng and Wang Fengyou.1999. Generality on natural forest protection projection [M]. Beijing: Chinese Forestry Publishing House, p43